Road closures and density and success of elk hunters in Idaho

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Abstract Relationships between the density of open (to motorized vehicles) and closed roads on public lands and the density and success of elk (*Cervus elaphus*) hunters were investigated in north-central Idaho, 1992–1995, to understand how hunter access influences elk harvest rates. Average annual hunter density and annual hunter success were 0.57±0.156 (SD) hunters/km^2/day and 14.8%±5.9, respectively, in a roaded area (RO) where the density of open roads was 1.54 km/km^2. In contrast, hunter density and success were 0.14± 0.025 hunters/km^2/day and 24.4%±4.4, respectively, in a managed access area (MA) where we reduced open-road density from 2.54 km/km^2 to 0.56 km/km^2 each year for the 25-day general elk season. In an "unroaded" area (UN), where open-road density was 0.23 km/km^2, hunter density and success were 0.18±0.033 hunters/km^2/day and 24.8%± 2.5, respectively. There may have been important differences in elk densities and terrain features that also contributed to these results. Inferences about the applicability of these findings to other areas should be made with caution because we had no spatial replicates. Nevertheless, the ability to reduce hunter densities and perhaps increase hunter success rates through managing road access appears to be a promising wildlife management tool.

Key words access management, *Cervus elaphus,* elk, hunter density, hunter success, Idaho, road closures

The influence of hunter access on the mortality of game has received increased attention as wildlife habitat has become more roaded (Fischer and Keith 1974, Fuller 1990, Unsworth et al. 1993, Rempel et al. 1997). Generally, hunting mortality of game species, including ruffed grouse (*Bonasa umbellus*), white-tailed deer (*Odocoileus virginianus*), and elk (*Cervus elaphus)*, has been greater along roads open to motorized vehicles and where open roads provide access to more habitat (Fischer and Keith 1974, Fuller 1990, Unsworth et al. 1993, Cole et al. 1997).

Conceptually, road access may influence hunting mortality through changes in hunter densities and, perhaps less obviously, hunter success rates. Although less hunting mortality of elk was associated with reduced densities of open roads and reduced hunter densities in Idaho (Leptich and Zager 1991, Unsworth et al. 1993), hunter density and open-road density were not correlated strongly within study areas (r_s<0.4; J. W. Unsworth, Idaho Department of Fish and Game, personal communication; Gratson et al. 1997), and changes in density of elk hunters with road closures elsewhere have been mixed (Burbridge and Neff 1976, Basile and Lonner 1979). Thus, the influence on hunter densities of managing hunter access through road closures is unclear.

Closing roads also may also influence hunter success rates by increasing elk use of habitat along roads (Wisdom 1998), by providing quiet access for hunters that results in increased rates of encounter

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between elk and hunters independently of elk distribution, and by attracting hunters with a different skill level (Gratson et al. 1997). Conversely, road closures did not appear to alter elk hunter success in Arizona (Burbridge and Neff 1976). Thus, the influence on hunter success of managing hunter access also remains unclear.

It is important to understand the impacts that access management has on hunter density and success because they may provide clues to causes of variability in the effects of access management on game survival. They also may provide clues to the acceptability of road closures as a game management tool by hunters, particularly on public lands. The objective of this study was to investigate how closing roads to motorized vehicles during elk seasons in north-central Idaho would influence hunter density and success. Together with work on the effects of road closures on hunting mortality of elk (Leptich and Zager 1991, Unsworth et al. 1993, Gratson et al. 1997) and on behaviors, demographics, and opinions of elk hunters in relation to road closures (Gratson et al. 1997), this study provides a better understanding of how managing hunter access might affect hunters and game survival.

Methods

Study area

The study area was in north-central Idaho along the Lochsa and Clearwater rivers between Pierce, Orofino, Lowell, and milepost 140 on United States Highway 12. Most of the study area was in public ownership (Clearwater National Forest, Idaho Department of Lands), but some of the western portion was owned by private timber corporations or small private farming and ranching operations. On those western private lands, the area was less rugged with smaller steep-sloped drainages and a patchwork of timbered and farmed parcels. In the central and eastern portions, the terrain was more rugged, with larger steep-sloped drainages dominated by forested and shrub habitats. Elevation ranged from 425 m at Syringa to 2,030 m on Castle Butte (Unsworth et al. 1993).

Study design

The study area was stratified into 3 adjacent areas where we investigated hunter densities and success in relation to hunter access: a roaded control area (RO), a road-closure or managed-access (MA) treatment area, and an "unroaded" (UN) comparison area. We had no spatial replicates, but we replicated the study across 4 general elk seasons, 1992–95. The general season was a 25-day, any-weapon, bull-only season from 10 October to 3 November.

Road densities were moderate to great because of timber-harvest activities on RO and MA areas. Total road density (closed roads plus open roads) in the 1,829-km^2 RO was 2.13 km/km^2. Some roads were closed to motorized vehicle use in RO so that open-road density was 1.54 km/km^2.

Total road density in a 312-km^2 MA was 2.52 km/km^2, but we closed most roads to all motorized vehicle use for the general elk season, starting in 1991, so that open-road density was 0.56 km/km^2. Gates with posted information on travel restrictions were installed on all closed roads to help prevent motorized vehicle use. We patrolled the MA daily during the first week of the season and during weekends and one weekday for the remainder of the season to reduce the likelihood that motorized vehicle use occurred on closed roads.

The 1,291-km^2 UN was largely unroaded, with total and open-road densities of 0.27 km/km^2 and 0.23 km/km^2, respectively.

Elk abundance and habitat features

Our study design assumed that factors other than road access that may be hypothesized to influence hunter densities and success (e.g., elk abundance, availability of trails, cover types, and ruggedness of terrain) were comparable across treatment areas. We tested this assumption by estimating post-season bull elk densities and, in 200 random 1-km^2 plots in each area, calculating trail density, mean slope, mean maximum differences in elevation, and percentages of plots that contained 3 cover types (light cover, shrub cover, timbered cover).

We approximated fall bull elk densities from 1988–93 winter sightability surveys, which accounted for sightability bias (Samuel et al. 1987, Steinhorst and Samuel 1989), but did not consider movement between fall and winter ranges. Movements of radiocollared bulls in treatment areas from 1991 to 1995 (n=231 bull-years) suggested that most adult elk moved from fall to winter ranges generally within treatment areas (M. W. Gratson, Idaho Department of Fish and Game, unpublished data).

We calculated trail densities from Geographic Information System (GIS) databases of the United States Forest Service, Idaho Department of Lands, and Potlatch Corporation and included open and closed (to motorized use) trails. Slope and elevation were obtained from United States Geological Survey Digital Elevation Model databases.

We obtained vegetation data from the Upper Columbia River Basin Assessment GIS database, which used Landsat Thematic Mapper 5 imagery (Redmond et al. 1996). We investigated light cover and shrub cover because they were associated with less and greater hunting season survival rates of bulls, respectively (Gratson et al. 1997). A quantitative description of cover types is included in the Results section of this paper.

Hunter sampling and telephone survey

Information on density and success of bull elk hunters was obtained using 2 sampling designs. One design consisted of obtaining a random sample of hunters encountered in the field and interviewing them after the season by telephone. Estimates of hunter density used only this sampling design. A township (93 km^2) and 32 km of roads open to car and truck travel were selected randomly in each treatment area each weekend day, holiday, and one (1993-1995) or all (1992) weekdays/week of the general elk season. If 32 km of roads in the first township were not available, we chose additional townships and roads randomly until we obtained 32 km of roads. We traveled selected roads and recorded locations, names, addresses, and telephone numbers of hunters or vehicle descriptions and license plate numbers if hunters were not available.

A second sampling design, used from 1993 to 1995, consisted of choosing a random sample of hunters from lists of potential elk hunters and interviewing them after the season by telephone. Estimates of hunter success combined data from this sampling design and samples of hunters encountered in the field. Lists of potential elk hunters consisted of names and telephone numbers of people who declared an intent (by purchasing a hunting license and elk tag the previous year) to hunt bull elk in game management units 10, 10A, or 12. Number of hunters selected randomly from lists was proportional to the size of each treatment area.

We attempted to interview by telephone all selected hunters. We called hunters between 3 November (end of season) and 25 December to reduce bias associated with recall (e.g., Mazurkiewicz et al. 1996). We used standardized procedures and a script for interviews. We asked hunters where they hunted each day of the elk season so that we could assign portions of hunter-days to subunits (portions of drainages) to provide estimates of variability of hunter density within treatment areas. We delineated subunits on maps we used during interviews. Subunits averaged 14.1 $km^2 \pm 5.27$ (SD). We assured hunters during interviews that we regarded information they provided us as confidential.

We modified raw estimates of hunter numbers according to sampling intensity of treatment areas and dates of the season to calculate annual estimates of hunter density (hunters/km^2/day) in treatment areas:

$$HD_t = \frac{\sum_{i=1}^{d} \frac{RN_{sdt}}{PT_{dt}}}{S_t}(D^{-1}),$$

where

$$PT_{dt} = \frac{\sum_{i=1}^{j} PR_{jdt}}{T_{td}}$$

and

HD_t = average hunter density in treatment area t,
RN_{sdt} = number of hunters reported hunting in subunit s on day d in treatment area t from telephone interviews of hunters encountered in the field,
PT_{dt} = proportion of each treatment area t sampled on day d,
PR_{jdt} = proportion of km of open roads available in sampled township j that was sampled on day d in treatment area t,
T_{td} = number of available townships in treatment area t on day d,
S_t = km^2 of treatment area t,
D = season length (days).

To characterize how hunter density changed among treatments during the 25-day season, we also calculated daily relative hunter density for each treatment as the proportion of the summed hunters/km^2/day during the season that each day contributed (daily hunter density/season hunter density).

We defined hunter success as the percentage of sampled hunters who reported killing a bull elk. We examined hunter success in relation to which treatment area hunters reported they hunted the most during a season. Harvest estimates from telephone interviews have been evaluated for elk hunters and were reported as reliable (Steinert et al. 1994).

We surveyed 16 hunters twice in the same year to evaluate consistency of their answers. We also interviewed 98 hunters during ≥ 2 hunting seasons to investigate movements by individual hunters among treatment areas.

Analyses

We used analyses of variance (ANOVA) to test for differences in annual average hunter density among treatment areas (Zar 1984, SPSS Inc. 1996). We used yearly averages as samples for ANOVA because estimates of hunter density for individual subunits within treatment areas were not independent (Hurlbert 1984). This analysis assumed that there was no interaction between year and treatment effects. An exploratory analysis using hunter density estimates in subunits within years suggested that there was no significant treatment by year interaction. We conducted pairwise comparisons of hunter density using the Bonferroni multiple comparisons adjustment (SPSS Inc. 1996).

We used chi-square analyses of contingency table data to test for differences in reported annual hunter success among treatment areas; we calculated 95% confidence intervals (CI) for yearly percentage estimates (Zar 1984, SPSS Inc. 1996). We first tested for sampling method effects (field sample versus list sample) with data pooled across years within treatment areas.

Results

Elk abundance and habitat features

There were differences among treatment areas in elk abundance and habitat features (Table 1). Total elk density and bull elk density during hunting seasons were probably greater in UN than MA, and densities were probably greater in MA than RO. In general, the RO was less rugged and had a lesser trail density, a slightly greater proportion of light cover, and a smaller proportion of shrub cover than MA or UN (Table 1).

Hunter density and success

Average annual hunter density (Table 2) varied among treatments ($F_{2,9} = 25.1, P<0.001$). Density was greater in RO than MA ($P<0.001$) and UN ($P = 0.001$), but there was no difference between MA and UN ($P>0.10$). Distribution of hunter density was not homogeneous within treatment areas. There was great variability in hunter density, particularly in RO.

Relative hunter density within areas changed during the hunting season and there were some differences in the pattern among areas (Figure 1). Relative density peaked on weekends and declined from the beginning to the end of the season, but peaks were less pronounced in UN and most pronounced in RO.

Reported hunter success (Table 3) varied among treatments ($\chi^2_2 = 16.3$, $P<0.001$), but not sampling

Table 1. Habitat and elk population characteristics of roaded (RO), managed access (MA), and unroaded (UN) areas in north-central Idaho, 1992–95.

	Roaded		Managed access		Unroaded	
Characteristic	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Elk density[a]	1.3	1.69	4.4	3.16	6.7	5.44
Bull elk density[a]	0.1	0.18	0.6	0.59	1.4	1.24
Slope	10.0	4.8	18.0	5.5	20.0	5.4
Elevation change (m)	202.0	114.0	396.0	145.0	451.0	168.0
Trail density[b]	0.1	0.18	0.4	0.68	0.3	0.43
Light cover[c] (%)	7.0	10.2	3.0	3.7	3.0	15.3
Shrub cover[d] (%)	4.0	7.3	17.0	15.3	23.0	21.6
Forested cover[e] (%)	36.0	24.5	38.0	21.5	34.0	22.9
n[f]	199		200		200	

[a] Animals/km^2 estimated in post-season aerial surveys.

[b] Km open and closed trail/km^2.

[c] Light cover included 5 cover type classes: those with <15% canopy coverage of shrubs or trees; low shrub cover (<0.76 m, >15% canopy coverage of shrubs and <15% coverage of trees) at 3 canopy coverages (low [15–39%], medium [40–69%], and high [>70%]); and, medium shrub cover types (0.76–1.98 m) at low canopy coverage.

[d] Shrub cover included 2 cover type classes: medium shrubs at medium canopy coverage and tall shrubs at medium canopy coverage.

[e] Timbered cover included 4 cover type classes: medium (22.9- to 53-cm dbh) tree (>15% canopy of trees) cover types at medium and high canopy coverage and large tree (>53-cm dbh) covertypes at medium and high canopy coverage.

[f] Number of random plots in which habitat features were estimated.

Table 2. Density of bull elk hunters (hunters/km²/day) in roaded (RO), managed access (MA), and unroaded (UN) areas in north-central Idaho, 1992–95.

	Roaded		Managed access		Unroaded	
Year	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
1992	0.49	1.215	0.18	0.166	0.21	0.386
1993	0.80	1.745	0.14	0.122	0.21	0.346
1994	0.51	1.186	0.12	0.176	0.18	0.293
1995	0.47	0.644	0.14	0.136	0.14	0.222
$\bar{x}$[a]	0.57A	0.156	0.14B	0.025	0.18B	0.033
n[b]	120		23		100	

[a] One-way ANOVA using annual means as samples: $F_{2,9}$= 25.1, P<0.001; within-row means followed by different letters differ significantly using Bonferroni multiple comparisons adjustment: RO versus MA (P<0.001) and UN (P=0.001), MA versus UN (P>0.10).

[b] Number of subunits sampled annually, except RO in 1995 when 58 subunits were sampled.

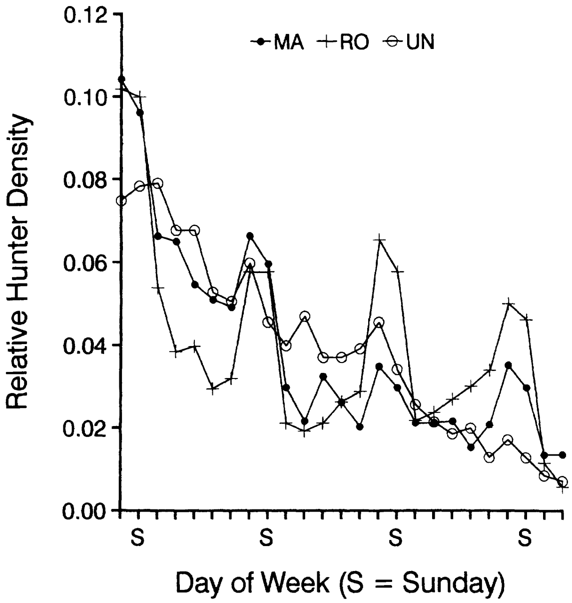

Figure 1. Proportion of total season hunter density in roaded (RO), managed access (MA), and unroaded (UN) areas that each day of the 1992 general elk season (10 October–3 November) contributed (daily hunter density/season hunter density).

methods (χ^2_1= 3.2, P = 0.07) or years (χ^2_3=4.9, P= 0.18). Success rates were less for RO than MA (χ^2_1= 11.1, P=0.001) or UN hunters (χ^2_1=14.6, P<0.001), but MA and UN hunters reported similar success rates (χ^2_1<0.01, P= 0.9).

Case histories

We interviewed 98 hunters 118 times during ≥2 years, all from field samples; we subsequently contacted 51 hunters one year later, 44 hunters 2 years later, and 23 hunters 3 years later. Of those hunters primarily hunting in RO during the initial year of contact, 71% (17/24) hunted the RO in subsequent years, 71% (29/41) of MA hunters subsequently hunted MA in later years, and 89% (47/53) of UN hunters subsequently hunted UN (χ^2_4= 103.8, P< 0.001).

Consistency of responses

We interviewed 16 bull elk hunters twice in the same year to examine consistency of answers for individual hunters. Eleven hunters were consistent across interviews in treatment areas they reported primarily hunting. Of the 5 other hunters, all reported during both interviews hunting ≥2 treatments, but for 4 hunters there was a small difference and for one hunter there was a large difference in the time they reported hunting different areas.

We categorized consistency in number of days hunters reported they hunted into 10 classes of 10%. There was a 0–10% difference between interviews in number of days hunters reported they hunted elk for 4 of 16 hunters, an 11–30% difference (combining 2 classes) for 6 hunters, a

Table 3. Reported success rates (%) of bull elk hunters in roaded (RO), managed access (MA), and unroaded (UN) areas in north-central Idaho, 1992–1995.

	Roaded		Managed access		Unroaded	
Year	Percentage	95% CI[a]	Percentage	95% CI[a]	Percentage	95% CI[a]
1992	19.4	6.5–37.7	28.8	6.5–37.7	23.6	13.9–34.9
1993	14.5	6.7–25.0	20.5	7.6–38.1	23.2	13.9–34.1
1994	18.7	7.5–34.1	20.6	6.9–39.6	28.4	18.6–39.3
1995	6.5	2.1–13.8	27.4	14.1–43.2	23.8	14.7–34.4
$\bar{x}$[b]	14.8A	5.9	24.4B	4.4	24.8B	2.5
n[c]	274		176		387	

[a] SD reported for means.

[b] Treatment area effects (χ^2_2=16.3, P<0.001); within-row means followed by different letters differ significantly: RO versus MA (χ^2_1=11.1, P=0.001) and UN (χ^2_1 =14.6, P<0.001), MA versus UN (χ^2_1<0.01, P=0.9).

[c] Number of hunters in sample.

Roads associated with logging provided greater access into the heart of elk habitat.

Closing roads to motorized access did not directly limit hunter numbers, but hunter densities were lower in closure areas than areas with open roads.

31-50% difference for 3 hunters, a 51-70% difference for 2 hunters, and between 71% and 80% difference for one hunter.

All hunters were consistent across interviews concerning their harvesting a bull elk that year.

Discussion

Study design

Inferences about the applicability of these results to other areas should be made with caution because we had no spatial replicates. Nevertheless, we had replicates of 4 elk seasons. Temporal replicates of treatments justify suggesting that our results likely apply to other times in and nearby our study areas. We first discuss factors other than open- and closed-road densities, such as elk densities and habitat and terrain features, that might be expected to influence hunter densities and success rates. This evidence partly addresses our lack of spatial replicates and hence the difficulty of determining whether results were from treatment effects or that areas were otherwise different. We chose the MA because prior to road closures this area was part of a large roaded area (Unsworth and Kuck 1991, Unsworth et al. 1993). We took a portion of that roaded area and applied a road-closure treatment (MA) and left the remainder RO.

Approximations of bull elk densities in control and treatment areas suggest it is unlikely that greater hunter densities in RO than MA were from greater bull densities rather than greater open-road densities. Bull densities were apparently less in RO. However, a potential confounding influence of elk densities on hunter success rates is less clear. Although there were consistent differences between RO and MA in estimates of bull densities and hunter success rates (RO<MA), estimates of bull densities differed greatly between MA and UN (MA<UN), but success rates (MA=UN) did not differ. These inconsistencies suggest that it is equivocal whether road closures likely resulted in greater success rates in MA or whether greater bull densities or lesser hunter:bull ratios (Vales et al. 1991) in MA likely resulted in greater success rates of MA than RO hunters. If lesser hunter:bull ratios were primarily responsible for greater success rates of MA hunters, we suggest that road closures may have resulted indirectly in greater success rates by reducing hunter densities.

Although habitat features differed among treatment areas (Table 1), it is unclear what inferences are possible regarding availability of habitat types and hunter densities and success rates. For example, it is unclear whether a greater proportion of lightly vegetated habitats would lead to greater or lesser hunter densities. Trail densities were greater on MA and UN areas and thus may not explain greater hunter densities in RO. The relatively great trail density in MA minimally influenced the number of hunters that used MA. However, greater trail densities could have led to greater success rates of MA and UN hunters. Similarly, it seems reasonable to presume that steeper terrain in MA and UN dissuaded hunters from hunting these areas in numbers comparable to the less rugged terrain of RO.

We also did not directly assess the extent that hunter densities in RO and UN were impacted by our adjacent MA because we did not conduct telephone interviews prior to road closures; nor did we ask hunters where they hunted before our study.

RO hunter densities may have been greater in our study area than similar but distant areas because hunters that traditionally hunted the MA before we implemented our road closures moved to the adjacent RO once we started our study. An estimate of 0.22 hunters/km^2/day in RO prior to this study (Unsworth and Kuck 1991), compared with a mean of 0.57 hunters/km^2/day in RO (Table 2) supports this possibility. We speculate that movement by hunters from areas where roads are closed to adjacent areas where roads are open was a likely consequence of road closures.


Many successful elk hunters used roadless or road-closure areas despite greater difficulty of access.

Hunter density

Despite limitations discussed above, our results support the conclusion that road closures may significantly reduce densities of elk hunters in north-central Idaho during general elk seasons (Table 2). Hunter densities in MA averaged 28% of RO in this study and 68% of an estimate of the same general area 5 years previously, where roads were open (Unsworth and Kuck 1991). In contrast, hunting pressure in central Montana was greater during years of restricted vehicle travel compared to years of unrestricted travel on one of 2 areas, whereas pressure was similar during years of restricted and unrestricted travel for the other area (Basile and Lonner 1979). Basile and Lonner (1979) attributed these differences to different habitat features on the 2 areas, particularly to the greater amount of total forest cover on the area where hunter pressure increased.

Mean hunter densities in our control and treatment areas were apparently greater than estimates that also included the archery season for the same general area (without a managed access area) 5 years previously (Unsworth and Kuck 1991), were less than densities for a 9-day season in a large enclosure in Oregon (range 0.6-1.6 hunters/km^2/day, Bryant et al. 1991), and were less than densities for the opening day in western Montana (mean of 0.68 hunters/km^2/day, range 0.5-5.0 hunters/km^2/day; L. J. Lyon, Rocky Mountain Research Station, Missoula, unpublished data), but were apparently comparable to estimates on similar areas in northern Idaho (mean 0.49 hunters/km^2/day, range 0-1.19 hunters/km^2/day, Leptich and Zager 1994).

Hunter success

Despite limitations of our study, results support the conclusion that road closures may lead to increased success rates of elk hunters in north-central Idaho (Table 3). Similarly, success rates of elk hunters in central Montana increased during years of restricted vehicle travel on one of 2 study areas compared to years of unrestricted travel (Basile and Lonner 1979). On the second area in central Montana, success rates were similar during years of restricted and unrestricted motorized access.

We suspect that greater success rates of MA than RO hunters were partly due to greater bull densities and lesser hunter:bull ratios (Vales et al. 1991), but we suggest that part of the greater success of MA hunters was from changes in both elk behavior and environmental factors associated with road closures and to the MA attracting a different type or skill level of hunter. For example, closed roads may have provided quiet access in elk habitat, leading to increased encounter rates between hunters and elk. Closing roads also may have increased elk use of habitat along roads due to the lack of motorized disturbance (Wisdom 1998), as elk can return within days to weeks after disturbance (Lyon and Ward 1982). Thus, rates of encounter between MA hunters and elk may have been greater along closed roads than encounter rates along open roads in RO. Although there were no differences among treatment areas in number of years that hunters hunted elk, number of elk killed in their lifetime was larger for MA than RO hunters (Gratson et al. 1997) and lifetime success has been identified as an important predictor of current success (Yuan 1992). Thus, despite similar levels of experience, MA hunters appeared to be more skillful than RO hunters.

Management implications

Access management has the potential to be an important tool to manage big-game harvest rates, at least on a local scale. Although there may have been important differences in elk densities or terrain and habitat features that also contributed to differences between roaded and road-closure areas in this study, we suggest that managers can generally expect, as we found, that hunter densities will decline and success rates may increase in road-closure compared to roaded areas. The implications of reduced hunter densities to hunting season survival rates of elk are clear (Vales et al. 1991, Unsworth et al. 1993). Reduced hunter density in our road-closure area contributed substantially to a 15-20% greater hunting season survival rate of bulls compared to a roaded area (Gratson et al. 1997). Further, survival rates and hunter densities were similar in road-closure and unroaded areas (Gratson et al. 1997). Similar impacts of road closures on hunting season survival of elk have been demonstrated in northern Idaho (Leptich and Zager 1991).

Managers should consider, however, that restricting access in only some areas will likely result in hunters going elsewhere to hunt, possibly creating greater densities of hunters in patches of habitat with unrestricted access or reduced participation in hunting. Thus, the result may be a landscape of patches of "high" vulnerability and "low" vulnerability habitats, conceptually similar to blocks with open and blocks with closed hunting seasons (McCullough 1996). Unless hunters quit the sport or game animals or their progeny disperse from closed-road patches to open-road patches, harvest or game-survival rates over a broad geographic scale may be similar to rates where access across all patches is unrestricted (Rempel et al. 1997). Dispersal characteristics of species, relative densities of local subpopulations, size and number of open-road and closed-road habitat patches, and "quitting" and moving characteristics of hunters may help determine whether managing road access results in greater regional survival rates of game. Managing game-survival rates by manipulating hunter density through block access management should be practiced within an adaptive framework (Walters 1986, Lancia et al. 1996) because of these continuing sources of uncertainty.

Despite this uncertainty, access management through road closures may be appealing to wildlife management agencies and the public because hunting opportunity remains relatively great compared to limiting numbers of hunters by controlled hunts or reducing season length. Moreover, as demonstrated in this study, success rates of hunters using road-closure areas can be greater than in roaded areas. Finally, reduced disturbance by motorized vehicles, reduced hunter numbers, and potentially greater success rates may provide a greater "quality" hunting experience for many hunters (McLaughlin et al. 1989).

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Literature cited

BASILE, J. V., AND T. N. LONNER. 1979. Vehicle restrictions influence elk and hunter distribution in Montana. Journal of Forestry 77:155-159.

BRYANT, L. D., J. W. THOMAS, B. K. JOHNSON, AND J. H. NOYES. 1991. Hunter and Rocky Mountain Elk (*Cervus elaphus nelsoni*) interactions in the Starkey Experimental Forest and Range. Pages 168-173 *in* A. G. Christensen, L. J. Lyon, and T. N. Lonner, editors. Proceedings of elk vulnerability - a symposium. Montana State University, 10-12 April 1991, Bozeman, USA.

BURBRIDGE, W. R., AND D. J. NEFF. 1976. Coconino National Forest-Arizona Game and Fish Department cooperative roads-wildlife study. Pages 44-57 *in* J. M. Peek, editor. Proceedings of elk-logging-roads symposium. University of Idaho, 16-17 December 1975, Moscow, USA.

COLE, E. K., M. D. POPE, AND R. G. ANTHONY. 1997. Effects of road management on movement and survival of Roosevelt elk. Journal of Wildlife Management 61:1115-1126.

FISCHER, C. A., AND L. B. KEITH. 1974. Population responses of central Alberta ruffed grouse to hunting. Journal of Wildlife Management 38:585-600.

FULLER, T. K. 1990. Dynamics of a declining white-tailed deer population in north-central Minnesota. Wildlife Monograph 110.

GRATSON, M.W., C.WHITMAN, AND P. ZAGER. 1997. Elk ecology - road closures and bull elk mortality: the effects of road closures on elk mortality in north-central Idaho; the effects of road closures on hunter density, distribution, and success in north-central Idaho. Idaho Department of Fish and Game, Federal Aid in Wildlife Restoration Project W-160-R-23, Final Report. Boise, USA.

HURLBERT, S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54:187-211.

LANCIA, R.A., ET AL. 1996. ARM! For the future: adaptive resource management in the wildlife profession. Wildlife Society Bulletin 24:436-442.

LEPTICH, D. J., AND P. ZAGER. 1991. Road access management effects on elk mortality and population dynamics. Pages 126-131 *in* A. G. Christensen, L. J. Lyon, and T. N. Lonner, editors. Proceedings of elk vulnerability - a symposium. Montana State University, 10-12 April 1991, Bozeman, USA.

LEPTICH, D. J., AND P. ZAGER. 1994. Coeur d'Alene elk ecology project - elk habitat security characteristics and hunting season mortality rates: hunting pressure in the Coeur d'Alene River drainage of Idaho; elk mortality during the fall hunting seasons in the Coeur d'Alene River drainage of Idaho. Idaho Department of Fish and Game, Federal Aid in Wildlife Restoration Project W-160-R-21, Progress Report. Boise, USA.

LYON, L. J., AND A. L. WARD. 1982. Elk and land management. Pages 443-477 *in* J. W. Thomas and D. E. Toweill, editors. Elk of North America, ecology and management. Stackpole, Harrisburg, Pennsylvania, USA.

MAZURKIEWICZ, S. M., K. J. BOYLE, M. F. TEISL, K. I. MORRIS, AND A. G. CLARK. 1996. Recall bias and reliability of survey data: moose hunting in Maine. Wildlife Society Bulletin 24:140-148.

MCCULLOUGH, D. R. 1996. Spatially structured populations and harvest theory. Journal of Wildlife Management 60:1-9.

MCLAUGHLIN, W. J., N. SANYAL, J. TANGEN-FOSTER, J. F. TYNON, S. ALLEN, AND C. C. HARRIS. 1989. 1987-88 Idaho rifle elk hunting study, volume 1: results. Idaho Forest, Wildlife and Range Experimental Station, Publication 499, University of Idaho, Moscow, USA.

REDMOND, R. L., Z. MA, T. P. TADY, J. C. WINNE, J. SCHUMACHER, J. TROUTWINE, S. W. HOLLOWAY, C. P. MCGUIRE, R. L. RIGHTER, M. M. HART, K. P. MCLAUGHLIN, AND W. A. WILLIAMS. 1996. Mapping existing vegetation and land cover across western Montana and northern Idaho. Final Report. Contract Number 53-0343-4-000012. United States Department of Agriculture, Forest Service, Missoula, Montana, USA. CD-ROM.

REMPEL, R. S., P. C. ELKIE, A. R. RODGERS, AND M. J. GLUCK. 1997. Timber-management and natural-disturbance effects on moose habitat: landscape evaluation. Journal of Wildlife Management 61:517-524.

SAMUEL, M. D., E. O. GARTON, M. W. SCHLEGEL, AND R. G. CARSON. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. Journal of Wildlife Management 51:622-630.

SPSS INC. 1996. SYSTAT 6.0 for windows: statistics. SPSS Inc., Chicago, Illinois, USA.

STEINERT, S. F., H. D. RIFFEL, AND G. C. WHITE. 1994. Comparisons of big game harvest estimates from check station and telephone surveys. Journal of Wildlife Management 58:335-340.

STEINHORST, R. K., AND M. D. SAMUEL. 1989. Sightability adjustment methods for aerial surveys of wildlife populations. Biometrics 45:415-425.

UNSWORTH, J. W. AND L. KUCK. 1991. Bull elk vulnerability in the Clearwater drainage of north-central Idaho. Pages 85-88 *in* A. G. Christensen, L. J. Lyon, and T. N. Lonner, editors. Proceedings of elk vulnerability—a symposium. Montana State University, 10-12 April 1991, Bozeman, USA.

UNSWORTH, J. W., L. KUCK, M. D. SCOTT, AND E. O. GARTON. 1993. Elk mortality in the Clearwater drainage of northcentral Idaho. Journal of Wildlife Management 57:495-502.

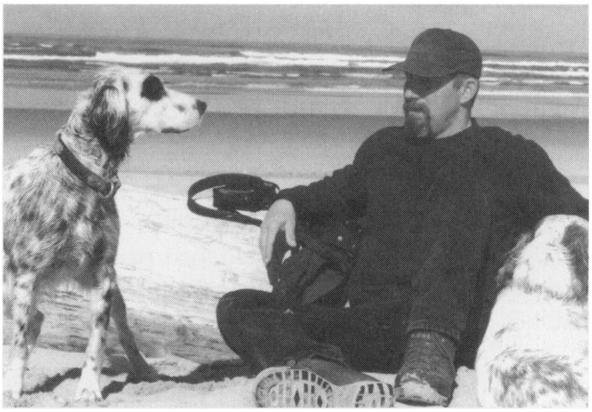
VALES, D. J., V. L. COGGINS, P. MATTHEWS, R. A. RIGGS. 1991. Analyzing options for improving bull:cow ratios of Rocky Mountain elk populations in northeast Oregon. Pages 174-181 *in* A. G. Christensen, L. J. Lyon, and T. N. Lonner, editors. Proceedings of elk vulnerability - a symposium. Montana State University, 10-12 April 1991, Bozeman, USA.

WALTERS, C. J. 1986. Adaptive management of renewable resources. MacMillan, New York, New York, USA.

WISDOM, M. J. 1998. Assessing life-stage importance and resource selection for conservation of selected vertebrates. Dissertation, University of Idaho, Moscow, USA.

YUAN, M. 1992. Estimating the effect of elk hunter behavior on hunter success 1989-1990. Research Report Number 19. University of Montana, Missoula, USA.

ZAR, J. H. 1984. Biostatistical analysis. Second edition. Prentice-Hall, Englewood Cliffs, New Jersey, USA.



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